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(54) **Method and apparatus for detecting inks**

Verfahren und Vorrichtung zum Erfassen von Tinten

Méthode et dispositif de détection d'encres

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Description

The invention relates to methods and apparatus for detecting the presence of an ink on a substrate.

It is known to print on substrates such as security documents and banknotes inks which, although appearing to have the same colour in the optical wavelength range, differ in their spectral absorption characteristics outside the optical range. We have devised a method and apparatus for detecting the presence of such inks.

GB-A-2107911 discloses a method and apparatus for detecting the presence of an ink on a substrate, the apparatus comprising irradiating means for irradiating the substrate with radiation of at least two different wavelengths, at least one of the wavelengths being chosen to correspond to an absorption or reflectance wavelength of the ink to be detected; modulation means for modulating the radiation at each wavelength in a respective, different manner; and radiation sensing means for sensing radiation emitted by the substrate.

In accordance with one aspect of the present invention, a method of detecting the presence of an ink on a substrate comprises irradiating the substrate with radiation at at least two different wavelengths, the radiation at each wavelength being modulated by a respective modulation signal in a respective, different manner, and at least one of the wavelengths being chosen to correspond to an absorption or reflection wavelength of the ink to be detected; and sensing radiation emitted from the substrate with a common sensor for receiving radiation at each of the different wavelengths to generate an output signal which represents the intensity of the received radiation, characterised by correlating samples of the sensed radiation with signals each of which is modulated by a respective one of the modulations applied to the radiation by feeding the output signal in parallel to a set of multipliers, each multiplier multiplying the output signal with a respective one of the modulated signals, and integrating each of the resultant multiplied signals over a cycle of the modulation, to generate correlation signals; wherein each modulation signal comprises a phase shifted version of a common modulation sequence which is a pseudo-random binary sequence; and monitoring the correlation signals in order to detect the presence of the said ink.

In accordance with a second aspect of the present invention, apparatus for detecting the presence of an ink on a substrate comprises irradiating means for irradiating the substrate with radiation at at least two different wavelengths, at least one of the wavelengths being chosen to correspond to an absorption or reflectance wavelength of the ink to be detected; modulation means for generating respective modulation signals for modulating the radiation at each wavelength in a respective, different manner; common radiation sensing means for sensing radiation emitted by the substrate and generating an output signal which represents the intensity of the received radiation; characterised in that the apparatus further comprises correlating means for correlating samples of the output signal with signals each of which is modulated by a respective one of the modulations applied to the radiation, to generate correlation signals wherein the correlating means comprises a number of multiplying circuits, one for each wavelength, each multiplying circuit receiving the output signal in parallel and a signal which has been modulated in the same way as the radiation wavelength corresponding to that multiplying circuit; and a corresponding number of integrating means to which the output signals from the multiplying circuits are fed, the integrating means integrating the incoming signals over a cycle of the modulation; wherein each modulation signal comprises a phase shifted version of a common modulation sequence which is a pseudo-random binary sequence; and monitoring means for monitoring the correlation signals in order to detect the presence of the said ink.

In our invention, the substrate such as a security document or banknote is irradiated with radiation at at least two different wavelengths and the response of the inks to the irradiation is monitored by modulating each wavelength in a unique manner and synchronously demodulating the received radiation by correlating that radiation with each of the modulation sequences. The result of the demodulation will be a number of correlation signals which vary in magnitude in accordance with the degree of correlation and the intensity of the received radiation at each wavelength. Provided that the modulations which are applied are sufficiently different, a correlation signal of a significant magnitude will only be generated when the received radiation includes a wavelength corresponding to the modulated signal which is correlated with it.

The invention has a number of advantages. In particular, broad band noise due, for example, to ambient light, is eliminated by the correlation technique. Also, the invention enables a single radiation receiver to be used.

The modulations comprise phase shifted versions of a common pseudo-random binary sequence. This leads to a very simple construction for the apparatus and enables well known correlation techniques to be adopted. This is discussed in more detail in "An Introduction to Identification" by J.P. Norton published by Academic Press (1986), pages 49-55.

It should be understood in this context that by "wavelength" we mean a band of wavelengths within which the wavelength in question is located, the wavelength bands not overlapping.

In any single apparatus according to the invention, the number of different wavelengths which can be used depends on the number of available modulations. Since phase shifted versions of a common modulation sequence are used, the number of wavelengths will depend on the length of the sequence.

To increase the number of wavelengths, a number of such apparatus according to the invention may be placed

side by side. Furthermore, by providing more than one apparatus, the presence of an ink on different parts of the substrate can be detected. In this case, if the modulations applied to each apparatus are different then each apparatus will be immune to stray irradiation from neighbouring apparatus.

The correlation signals may be monitored in a variety of ways. For example, where one signal corresponds to radiation in the optical waveband and another signal to radiation outside the optical waveband (for example infra-red) then the signals may be compared with each other or a ratio between the signals may be determined, the result of either of these operations being compared with a previously determined value to indicate the presence or absence of the ink. Thus, where two inks have the same colour in the optical waveband and different spectral responses outside the optical waveband, then the ratio between the respective signals will differ depending upon which ink is being irradiated.

The invention is applicable in a wide variety of applications but is particularly suitable for use with banknote sorting machines in which banknotes are sorted into acceptable and unacceptable types depending upon the presence or absence respectively of certain inks.

Typically, the radiation which is sensed will have been reflected from the substrate although alternatively radiation passing through the substrate could be sensed.

In order that the invention may be better understood, an example of a method and apparatus for detecting the presence of an ink on a document in accordance with the present invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a block diagram of the apparatus;
Figures 2A and 2B illustrate two modulation sequences; and,
Figures 2C and 2D illustrate the signals output at two positions in the apparatus.

The apparatus shown in Figure 1 comprises a number n of light emitting diodes (LEDS) 1 which generate radiation at a corresponding number of different wavelengths some of which are in the optical range and some of which are outside the optical range, typically in the infrared range. The LEDS 1 irradiate a document 2 which is carried beneath the LEDS by means not shown. The wavelength of the radiation generated by at least one of the LEDs 1 is chosen to correspond with an absorption band of an ink which is expected to be printed on the document.

A single detector 3 is positioned above the document 2 to receive radiation reflected by the document. Alternatively, the detector 3 could be below the document.

The LEDs 1 are controlled by respective control lines 4 from a sequence generator 5 to generate respective modulated radiation beams in a manner to be described below. The sequence generator 5 generates respective modulation signals which are fed to the LEDs 1 which then generate the modulated radiation beams.

The output signal from the detector 3 which represents the intensity of the incident radiation on the detector 3, the detector 3 being responsive to all wavelengths generated by the LEDs 1, is fed in parallel to a set of multiplying circuits 6, one for each LED. In addition, each multiplier 6 receives the modulation signal from the sequence generator 5 corresponding to the associated LED 1, via respective lines 7.

The output signals from the multipliers 6 are fed to respective integrating circuits 8, the output signals from the Integrators being fed to a microprocessor 9. The microprocessor 9 monitors the incoming (correlation) signals and generates output signals related to the inks which are detected as a result of that monitoring, the output signals being fed to an output device 10 such as a monitor or printer.

Since a common detector 3 is provided, it is necessary for the apparatus to distinguish between the different wavelengths of radiation which are reflected by the document 2. This is achieved by uniquely encoding each irradiation source (LED) 1 by modulating it with a pseudo random binary sequence (PRBS) generated by the sequence generator 5. An example of such a sequence is shown in Figure 2A. In order that each LED 1 is modulated with a different sequence, differently phase shifted versions of the sequence shown in Figure 2A are fed to the other LEDs 1. An example of a phase shifted version of the sequence is shown in Figure 2B.

The PRBS is a broad band signal with a correspondingly narrow autocorrelation function. This property is used to discriminate different signals or channels from one another. The autocorrelation function of the signal describes how well a signal correlates with shifted versions of itself and in the case of the PRBS this function will be zero unless the incoming signal is correlated with the same modulation sequence that generated it. In this way, noise due to ambient light and the like as well as stray light from other adjacent apparatus and wavelengths not associated with a particular channel are automatically eliminated.

Correlation is achieved by multiplying the two signals together in the multiplying circuits 6 which generate an output of the form shown in Figure 2C and subsequently integrating the result in the integrators 8 which generate an output of the form shown in Figure 2D. This system correlates the returned signal with each of the irradiation modulation sequences.

The correlation result used by the system processor can be defined mathematically as:

$$\emptyset(nT) = \emptyset(nT - T) \quad \text{for } t \neq nT \quad n = 0 \ldots \infty$$
$$= \emptyset(t) \quad \text{for } t = nT$$
$$\text{and } \emptyset(t) = 0 \quad \text{if } t = nT + \delta T$$
$$= \frac{1}{A} \int_{nT + \delta T}^{nT + T} x(t)\, x(t + \tau)\, dt \quad \text{(a contiunous function)}$$

where

n	is the sample number
T	is the integration period
x(t)	is the original sequence (FIG. 2A)
$x(t + \tau)$	is the phase shifted sequence (FIG 2B)
A	is a scaling factor dependent on the system response.

The output signals from the integrators 8 indicate whether or not the wavelength associated with a particular channel has been reflected by the document 2 and in that case may indicate the presence of a particular ink which has the characteristic of reflecting radiation within that particular wavelength band. In practice, although n channels have been shown in Figure 1, a typical system would make use of just two channels.

The correlation signals are then compared by the microprocessor 9. In the case where just two channels are provided (corresponding for example to respective wavelengths in and out of the optical band), this comparison may involve determining the difference between the correlation signals and/or the ratio between the correlation signals and then comparing these values with predetermined calibration windows or thresholds. If the computed results fall within the windows or above the thresholds then an output signal is provided to the output device 10 indicating the presence of the ink concerned. This indication can then be used to control the feeding of the document in a conventional manner.

Claims

1. A method of detecting the presence of an ink on a substrate, the method comprising irradiating the substrate with radiation at at least two different wavelengths, the radiation at each wavelength being modulated by a respective modulation signal in a respective, different manner, and at least one of the wavelengths being chosen to correspond to an absorption or reflection wavelength of the ink to be detected; and sensing radiation emitted from the substrate with a common sensor for receiving radiation at each of the different wavelengths to generate an output signal which represents the intensity of the received radiation, characterised by correlating samples of the sensed radiation with signals each of which is modulated by a respective one of the modulations applied to the radiation by feeding the output signal in parallel to a set of multipliers, each multiplier multiplying the output signal with a respective one of the modulated signals, and integrating each of the resultant multiplied signals over a cycle of the modulation, to generate correlation signals; wherein each modulation signal comprises a phase shifted version of a common modulation sequence which is a pseudo-random binary sequence; and monitoring the correlation signals in order to detect the presence of the said ink.

2. A method according to claim 1, wherein one of the wavelengths lies in the optical range, and another of the wavelengths lies outside the optical range.

3. A method according to any of the preceding claims, wherein the sensing step comprises sensing radiation reflected by the substrate.

4. Apparatus for detecting the presence of an ink on a substrate, the apparatus comprising irradiating means (1) for irradiating the substrate (2) with radiation at at least two different wavelengths, at least one of the wavelengths being chosen to correspond to an absorption or reflectance wavelength of the ink to be detected; modulation means (5) for generating respective modulation signals for modulating the radiation at each wavelength in a respective, different manner; common radiation sensing means (3) for sensing radiation emitted by the substrate and generating an output signal which represents the intensity of the received radiation; characterised in that the apparatus

further comprises correlating means (7,8) for correlating samples of the output signal with signals each of which is modulated by a respective one of the modulations applied to the radiation, to generate correlation signals wherein the correlating means comprises a number of multiplying circuits (7), one for each wavelength, each multiplying circuit receiving the output signal in parallel and a signal which has been modulated in the same way as the radiation wavelength corresponding to that multiplying circuit; and a corresponding number of integrating means (8) to which the output signals from the multiplying circuits are fed, the integrating means integrating the incoming signals over a cycle of the modulation; wherein each modulation signal comprises a phase shifted version of a common modulation sequence which is a pseudo-random binary sequence; and monitoring means (9) for monitoring the correlation signals in order to detect the presence of the said ink.

5. A method according to any of claims 1 to 3, wherein the substrate comprises a banknote.

Patentansprüche

1. Verfahren zum Feststellen der Anwesenheit einer Tinte auf einem Substrat, wobei das Verfahren beinhaltet: das Bestrahlen des Substrats mit einer wenigstens zwei verschiedene Wellenlängen aufweisenden Strahlung, wobei die Strahlung jeder Wellenlänge jeweils durch ein Modulationssignal in unterschiedlicher Weise moduliert wird und wenigstens eine der Wellenlängen so gewählt ist, daß sie einer Absorptions- oder Reflexionswellenlänge der festzustellenden Tinte entspricht, und das Abfühlen der vom Substrat reflektierten Strahlung mit einem gemeinsamen Fühler zum Empfangen von Strahlung mit jeder der verschiedenen Wellenlängen, um ein Ausgangssignal zu erzeugen, das die Intensität der empfangenen Strahlung darstellt, gekennzeichnet durch das Korrelieren von Abtastwerten der abgefühlten Strahlung mit Signalen, von denen jedes durch jeweils eine der auf die Strahlung angewandten Modulationen moduliert wird, indem das Ausgangssignal parallel einer Gruppe von Multiplizierern zugeführt wird, wobei jeder Multiplizierer das Ausgangssignal mit jeweils einem der modulierten Signale multipliziert, und die Integration jedes der resultierenden multiplizierten Signale über eine Periode der Modulation, um Korrelationssignale zu erzeugen; wobei jedes Modulationssignal eine phasenverschobene Version einer gemeinsamen Modulationssequenz umfaßt, bei der es sich um eine binäre Pseudo-Zufalls-Sequenz handelt; und das Überwachen der Korrelationssignale zum Feststellen der Anwesenheit der erwähnten Tinte.

2. Verfahren nach Anspruch 1, bei dem eine der Wellenlängen im optischen Bereich und eine andere außerhalb des optischen Bereichs liegt.

3. Verfahren nach einem der vorstehenden Ansprüche, bei dem das Abfühlen das Abfühlen der durch das Substrat reflektierten Strahlung umfaßt.

4. Vorrichtung zum Feststellen der Anwesenheit einer Tinte auf einem Substrat, wobei die Vorrichtung Bestrahlungsmittel (1) zum Bestrahlen des Substrats (2) mit einer wenigstens zwei verschiedene Wellenlängen aufweisenden Strahlung, von denen wenigstens die eine Wellenlänge so gewählt ist, daß sie einer Absorptions- oder Reflexionswellenlänge der festzustellenden Tinte entspricht; Modulationsmittel (5) zum Erzeugen jeweiliger Modulationssignale zum Modulieren der Strahlung jeder Wellenlänge in jeweils unterschiedlicher Weise; und gemeinsame Strahlungsfühlmittel (3) zum Abfühlen der durch das Substrat emittierten Strahlung und zum Erzeugen eines Ausgangssignals, das die Intensität der empfangenen Strahlung darstellt, aufweist, dadurch gekennzeichnet, daß die Vorrichtung ferner ein Korrelationsmittel (7, 8) zum Korrelieren von Abtastwerten des Ausgangssignals mit Signalen aufweist, die jeweils durch eine der auf die Strahlung angewandten Modulationen moduliert sind, um Korrelationssignale zu erzeugen, wobei das Korrelationsmittel aufweist: eine Anzahl von Multiplizierschaltungen (7), und zwar jeweils eine für jede Wellenlänge, wobei jede Multiplizierschaltung das Ausgangssignal parallel und ein Signal empfängt, das auf die gleiche Weise wie die Strahlungswellenlänge moduliert ist, die jener Multiplizierschaltung entspricht; und eine entsprechende Anzahl von Integrationsmitteln (8), denen die Ausgangssignale der Multiplizierschaltungen zugeführt werden, wobei die Integrationsmittel die Eingangssignale über eine Periode der Modulation integrieren; wobei jedes Modulationssignal eine phasenverschobene Version einer gemeinsamen Modulationssequenz aufweist, bei der es sich um eine binäre Pseudo-Zufalls-Sequenz handelt; und Überwachungsmittel (9) zum Überwachen der Korrelationssignale, um die Anwesenheit der erwähnten Tinte festzustellen.

5. Verfahren nach einem der Ansprüche 1 bis 3, bei dem das Substrat eine Banknote aufweist.

Revendications

1. Méthode de détection de la présence d'encre sur un substrat, la méthode comportant l'irradiation du substrat par rayonnement à un minimum de deux longueurs d'onde différentes, le rayonnement à chaque longueur d'onde étant modulé par un signal respectif de modulation et d'une manière respective différente, et le minimum d'une des longueurs d'onde étant sélectionnée de manière à correspondre à une longueur d'onde d'absorption ou de réflection de l'encre à capter; et la détection du rayonnement émis par le substrat, à partir d'un détecteur commun de réception du rayonnement à chacune des longueurs d'onde différente qui représente l'intensité du rayonnement ainsi reçu, caractérisé par la corrélation d'échantillons de rayonnement détecté avec des signaux dont chacun est modulé selon l'une des modulations respectives appliquées au rayonnement en apportant le signal de sortie en parallèle à un jeu de multiplicateurs, dont chaque multiplicateur multiplie le signal de sortie par l'un des signaux respectifs modulés, et l'intégration de chacun avec les signaux multipliés qui en résultent dans un cycle de modulation, pour générer des signaux de corrélation; dont chaque signal de modulation comporte une version déphasée d'une séquence de modulation commune qui est séquence binaire pseudo-aléatoire; et la surveillance des signaux de corrélation afin de capter la présence de ladite encre.

2. Méthode suivant la revendication 1, selon laquelle une des longueurs d'onde se situe dans la fourchette optique, et une autre des longueur d'ondes se situe hors de la fourchette optique.

3. Méthode suivant l'une ou l'autre des revendications précédentes, selon laquelle la phase de détection comporte la détection du rayonnement reflété par le substrat.

4. Appareil de détection de la présence d'encre sur un substrat, l'appareil comportant des moyens d'irradiation (1) pour irradier le substrat (2) avec un rayonnement situé au minimum en deux longueurs d'onde différentes, une des longueurs d'ondes au minimum étant sélectionnée pour correspondre à une longueur d'onde d'absorption ou de réflectance de l'encre à détecter; des moyens de modulation de rayonnement à chacune des longueurs d'onde en une manière respective différente; des moyens communs de rayonnement (3) pour détecter le rayonnement émis par le substrat et pour générer un signal de sortie qui représente l'intensité du rayonnement reçu; caractérisé en ce que l'appareil comporte en outre des moyens de corrélation (7,8) permettant la corrélation d'échantillons du signal de sortie avec des signaux dont chacun est modulé par l'une des modulations respectives appliquée au rayonnement, pour générer les signaux de corrélation suivant lequel les moyens de corrélation comportent une série de circuits multiplicateurs (7), dont un à chaque longueur d'onde, chaque circuit multiplicateur recevant le signal de sortie en parallèle et un signal qui a été modulé de même manière que la longueur d'onde de rayonnement correspondant au circuit multiplicateur; et un nombre correspondant de moyens d'intégration (8) auxquels sont apportés les signaux de sortie provenant des circuits multiplicateurs, les moyens d'intégration assurant l'intégration des signaux dans un cycle de modulation; selon lequel chaque signal de modulation comporte une version déphasée d'une séquence commune de modulation qui est une séquence binaire pseudo-aléatoire; et des moyens de surveillance (9) pour la surveillance des signaux de corrélation afin de détecter la présence de ladite encre.

5. Méthode suivant l'une ou l'autre des revendications 1 à 3,selon laquelle le substrat comporte un billet de banque.

Fig.1

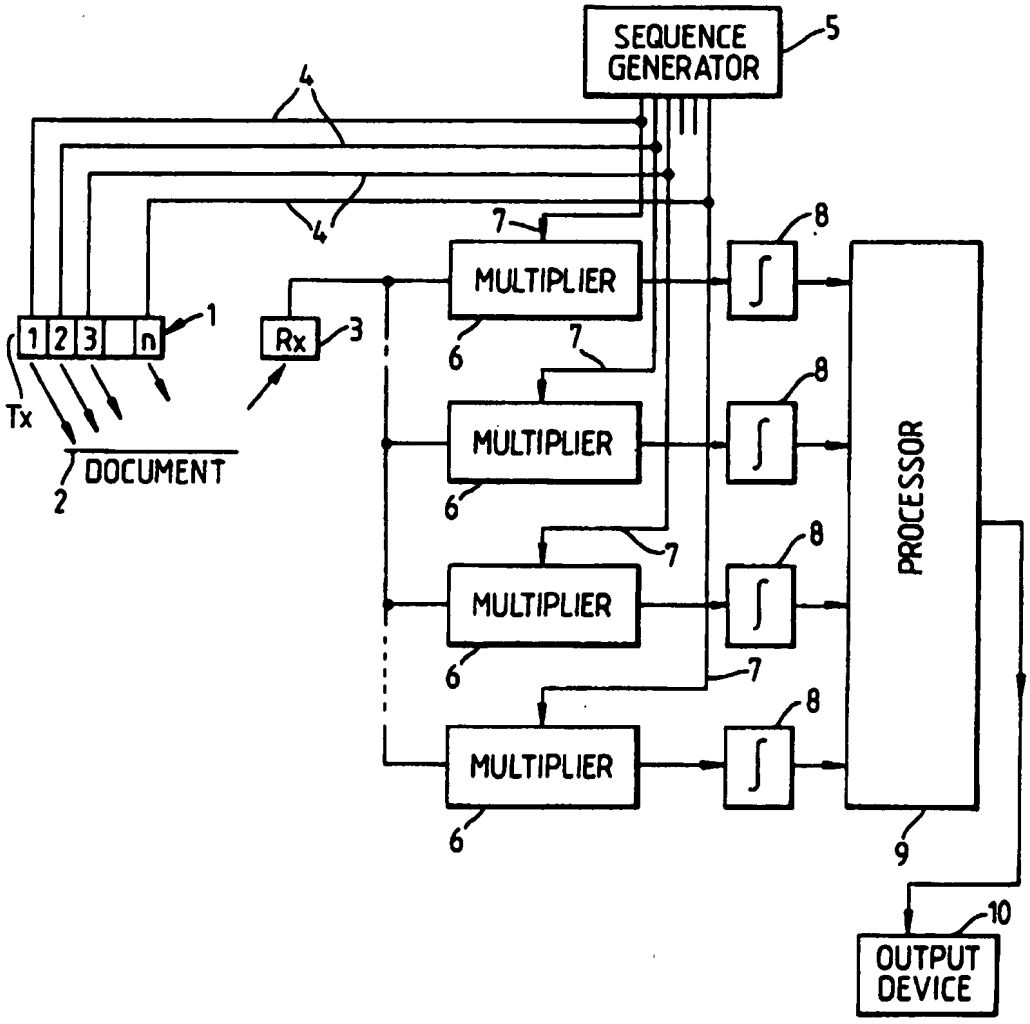

SEQUENCE GENERATOR
5
4
4
7
8
MULTIPLIER
1
2
3
n
Rx
3
Tx
DOCUMENT
2
6
7
MULTIPLIER
8
6
7
MULTIPLIER
8
6
7
MULTIPLIER
8
6
PROCESSOR
9
10
OUTPUT DEVICE

Fig.2A 

Fig.2B 

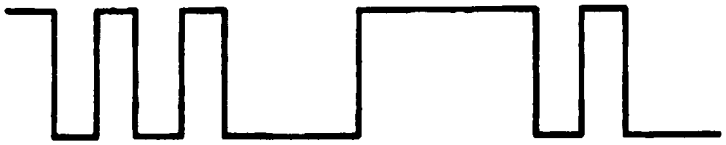
Fig.2C 

Fig.2D